Advanced Processing of the Optical Surface on Large Lightweight Mirrors

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OUTLINE

* Objectives
* Technical Approach (Replication Technique)
  - SiC/Si_3N_4 Nano-Laminate
  - Negative CTE Powder/CDD Processed Composite
* Critical Issues
* Preliminary Experimental Results
  - Nano-Laminate Deposition
  - Geopolymerization
  - Negative CTE Nano-Powder Synthesis
  - Chemically Driven Densification (CDD)
* Summary and Future Work for Next Few Months

OBJECTIVES

* Deposition Processing Optimization:

  SiC/Si_3N_4 Alternating Nano-Laminate

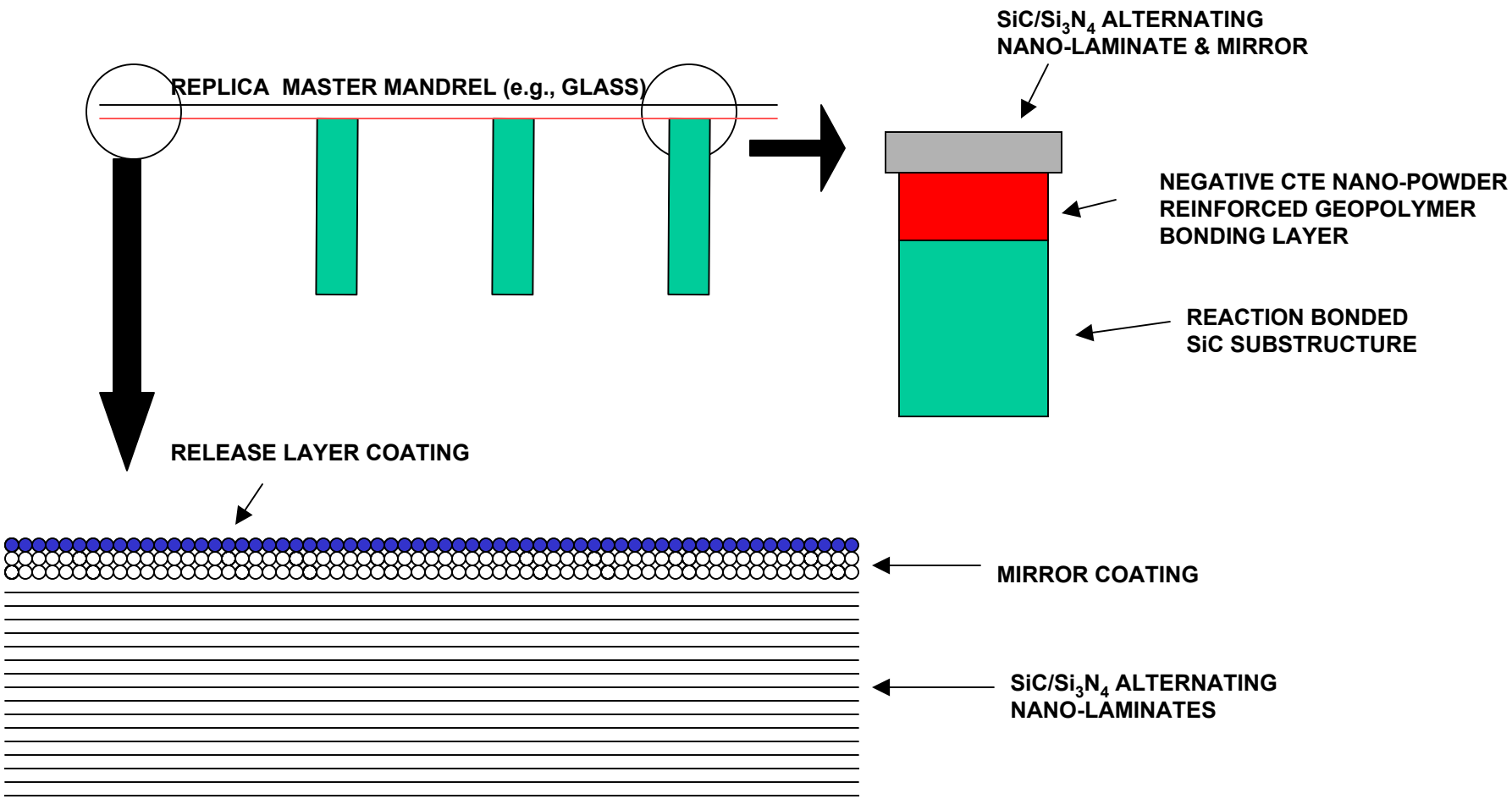
  Release Layer Coating/Concept

* Production of –CTE Nano-Powder in large Quantity

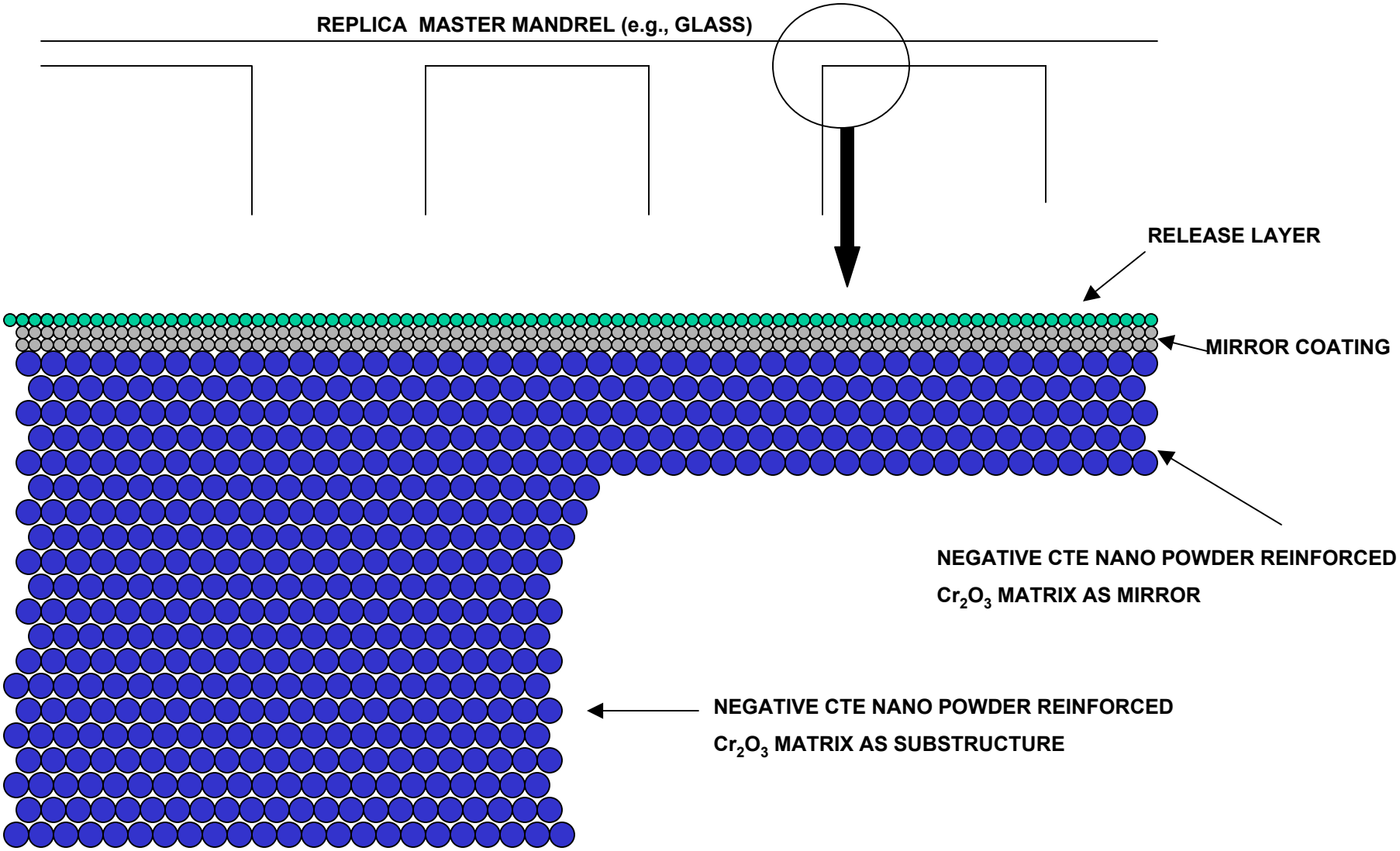
* -CTE Powder/Geopolymer Composite Fabrication and Bond Strength measurement of SiC/SiC

* -CTE Nano-Powder/CDD Composite Fabrication

Schematic Drawing of SiC/Si_3N_4 Nano-Laminate Mirror Assembly Concept



Schematic Drawing of - CTE Nano-Powder Reinforced CDD Processed Uni-Body Composite Mirror Assembly Concept



CRITICAL ISSUES

* Release Layer Coating/Concept :

  Easy Release from Master Mandrel without Distortion

* SiC/Si_3N_4 Alternating Nano-Laminate :

  Microstructural Uniformity within the Layer

  Mechanical Strength of the Laminate vs. # of Layers

* -CTE Powder/Geopolymer Composite Bond :

  Adequate Bond Strength for SiC/SiC Joint

* -CTE Powder/CDD Composite Fabrication

  Large Negative CTE Nano-Powder production

  Exothermic Reaction Control (-CTE powder, Mandrel, etc.)

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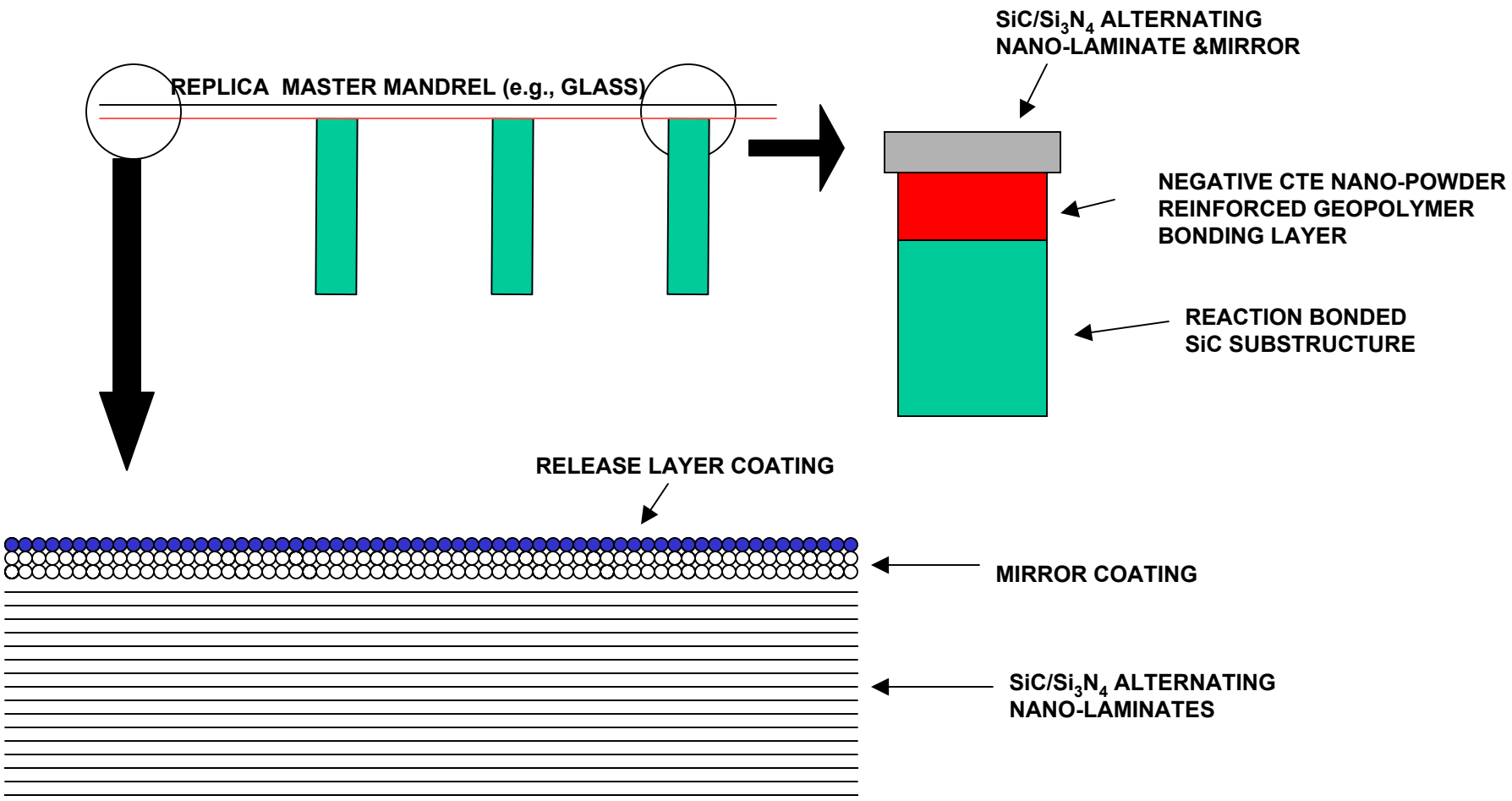


EXPERIMENTAL RESULTS

Single Component Magnetron Sputtering Deposition

SiC : Deposition Optimization (7 trials) by Varying Argon Flow Rate and Chamber Pressure and Deposition Time and Distance from Target to Si Substrate

Si_3N_4 : Deposition Parameter Optimization Started

Fugitive Release Layer

KBr : Thermal Evaporation Deposition

SiO_2 : Thermally Grown on Si

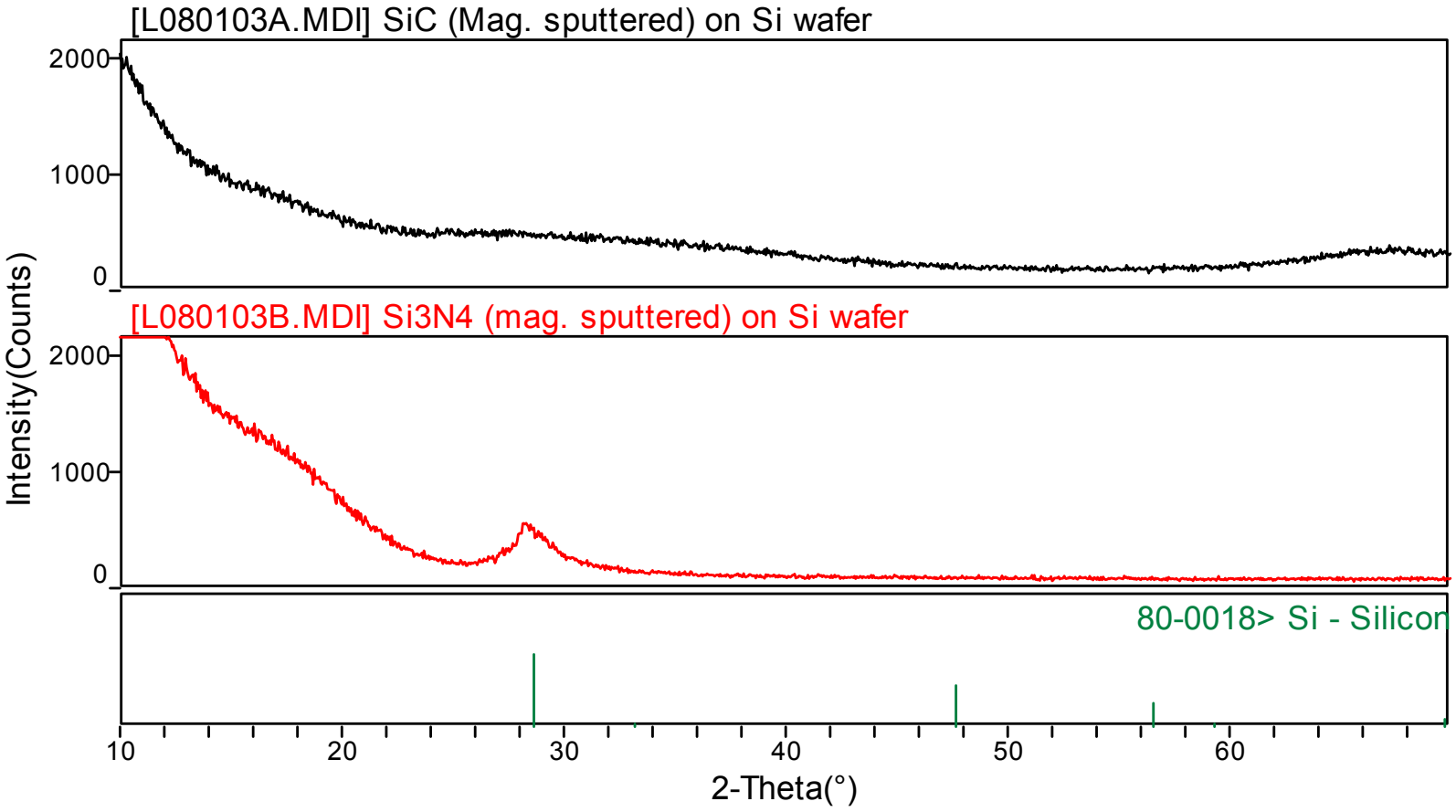
SiC/Si_3N_4 Alternating Multi-Layer Deposition

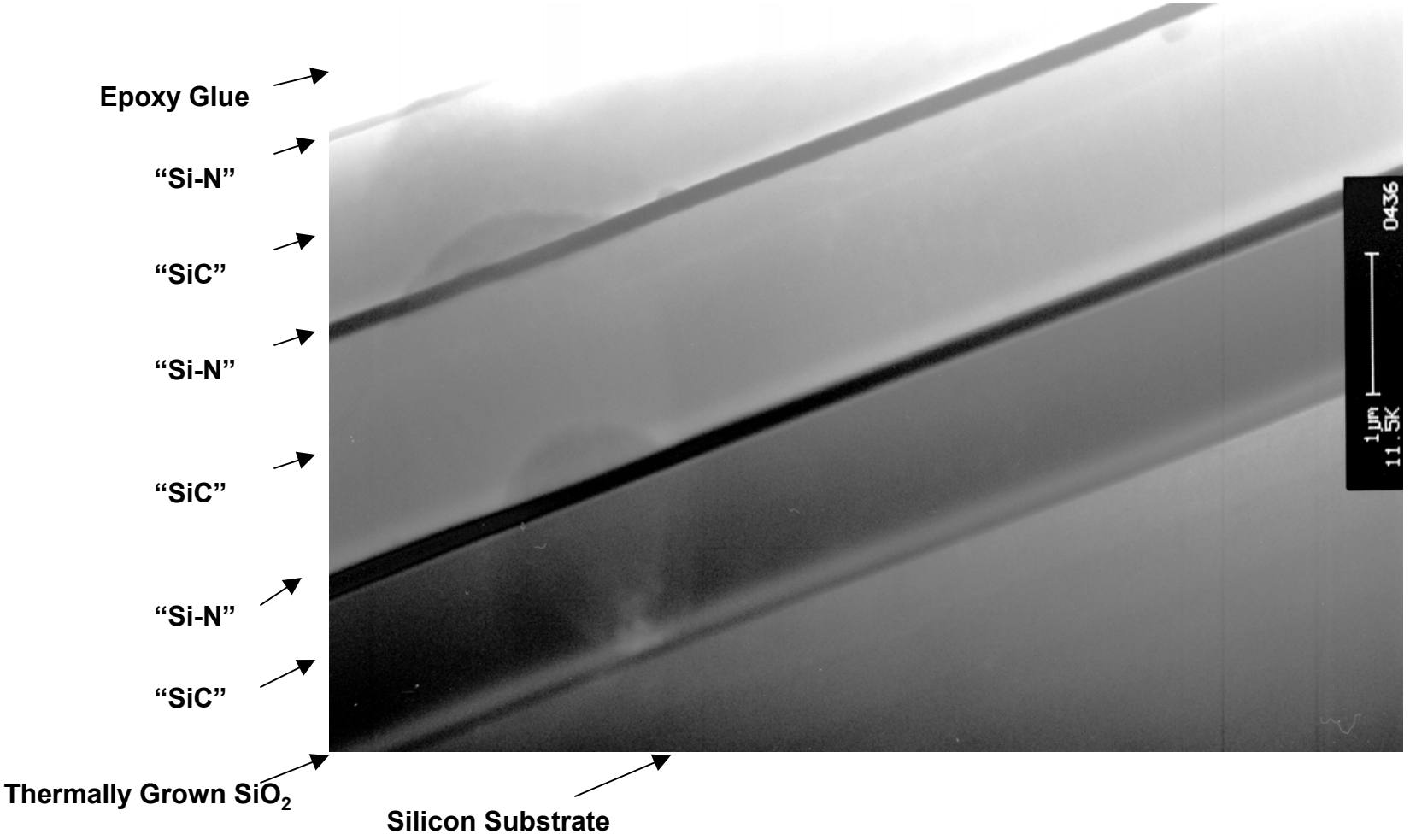
7 Alternating Layers on with and without SiO_2 Release layer

XRD and Cross-sectional SEM/TEM micrographs

XRD on Single components revealed Amorphous

XRD Patterns of SiC and Si_3N_4 Coatings on Si Wafer Showing Amorphous nature of the Coatings





Cross-Sectional TEM Micrograph of Multi-Layer Coating (The Compositions of the Coating Layers are Tentative)

Potential negative CTE oxides

(CTE Range = -5 ~ -9 x 10^{-6}/K)

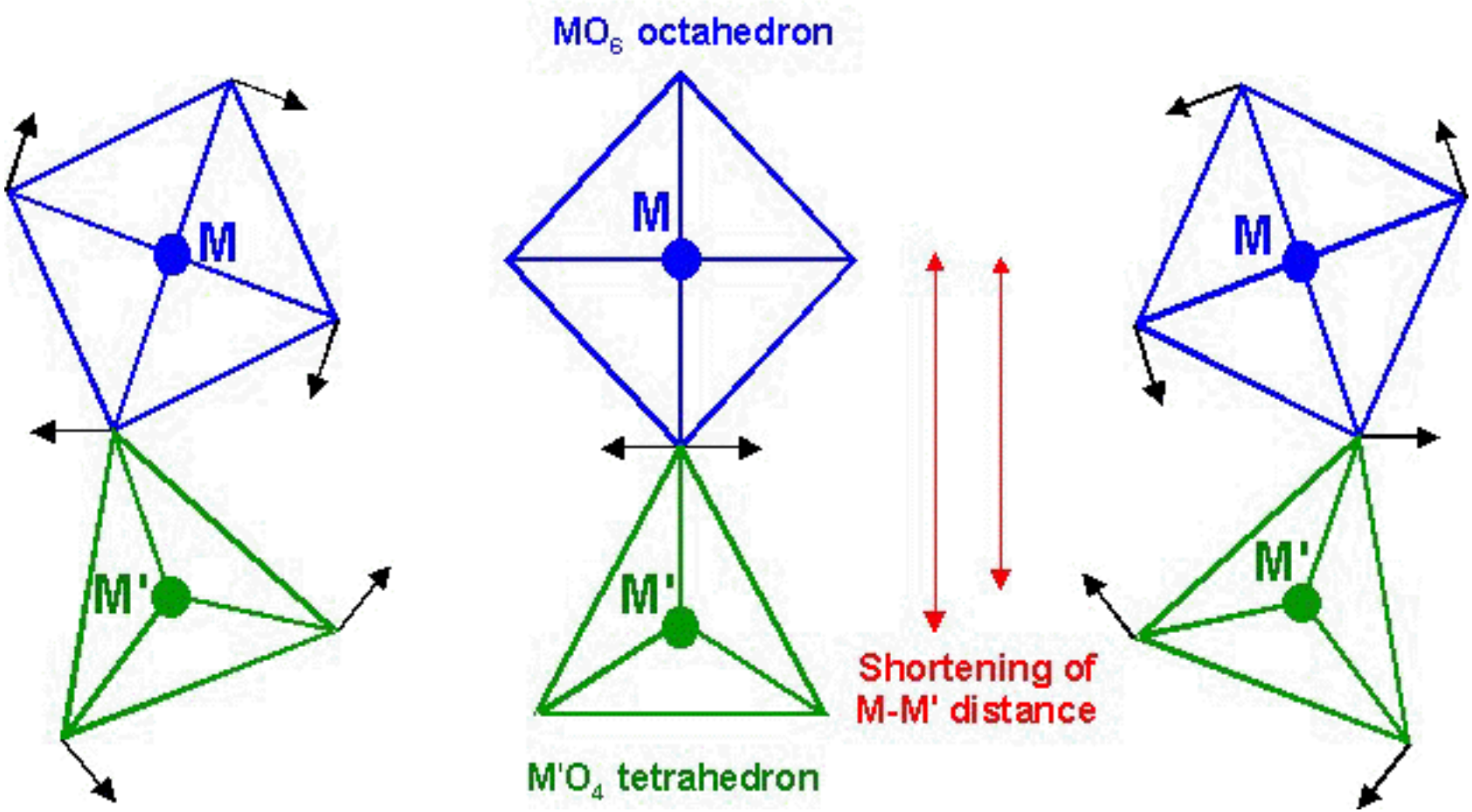
Cubic:

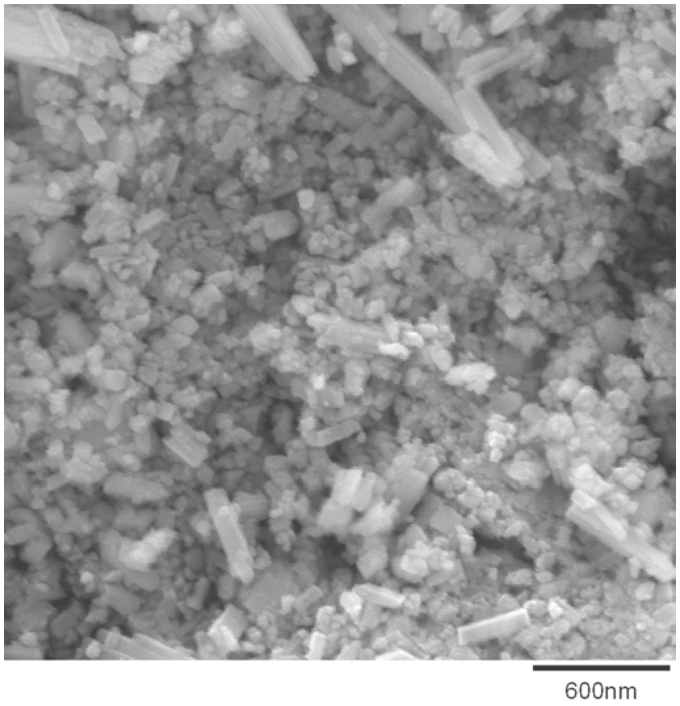
- ZrW_2O_8
- $ZrMo_2O_8$
- $ZrW_2Mo_{2-x}O_8$

Orthorhombic:

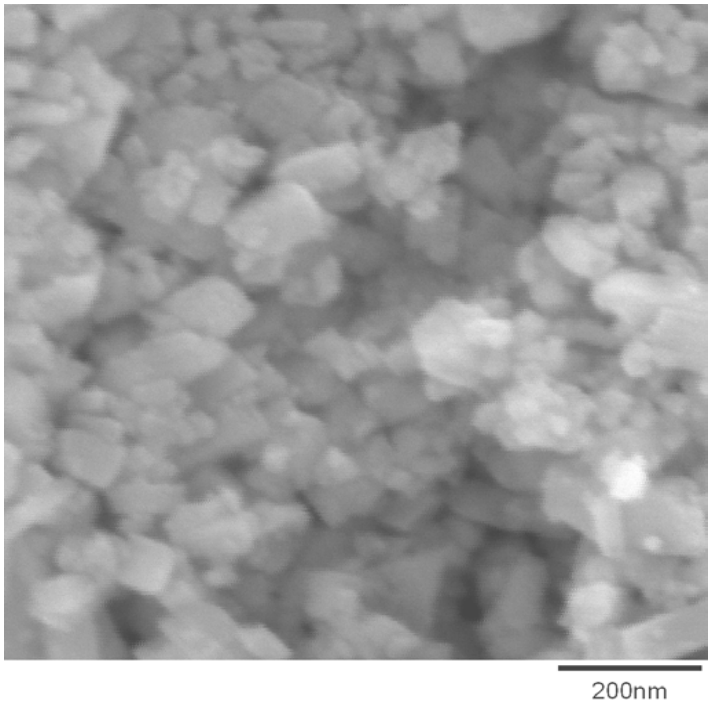
- $Y_2W_3O_{12}$

Origin of Negative CTE





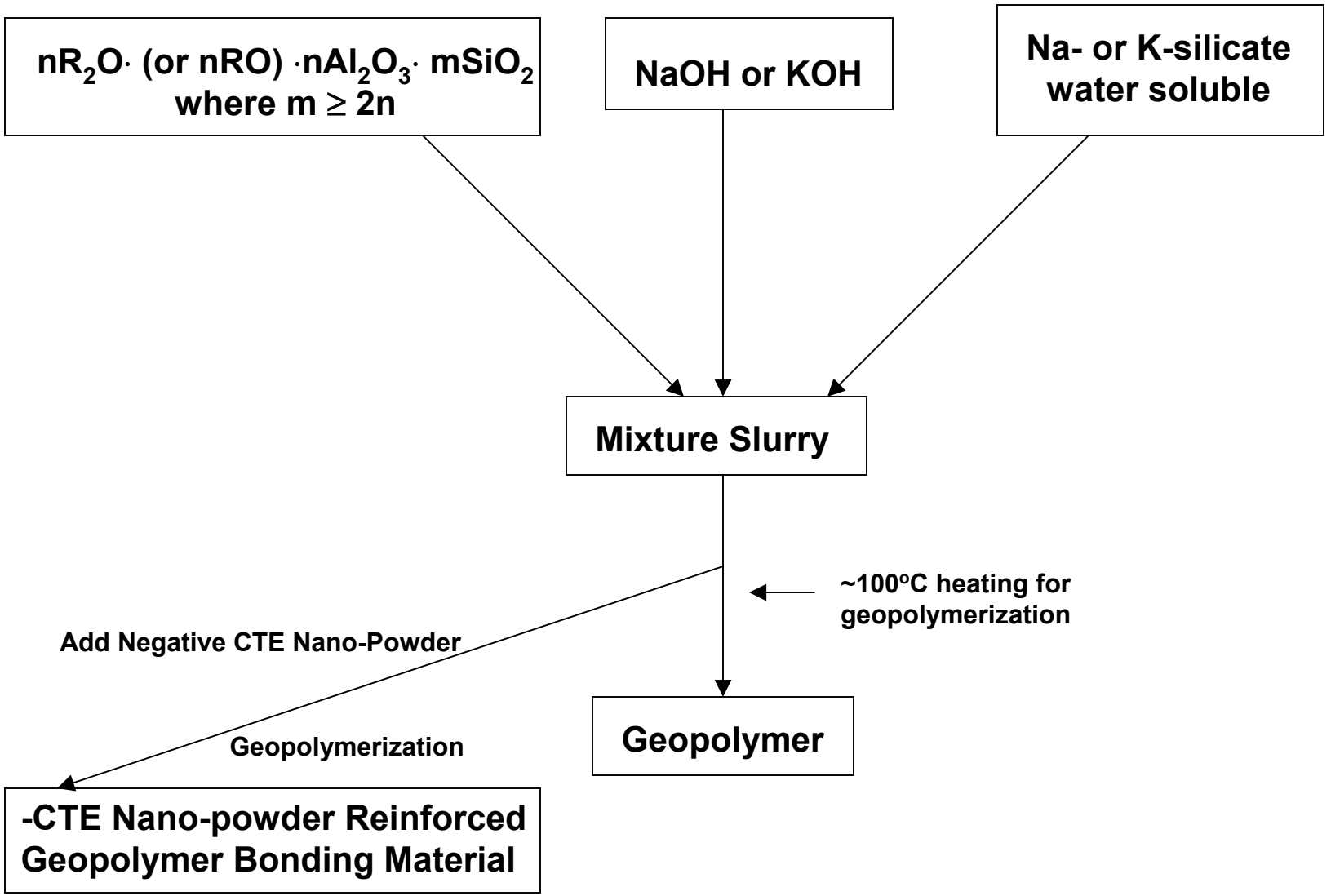
(a)



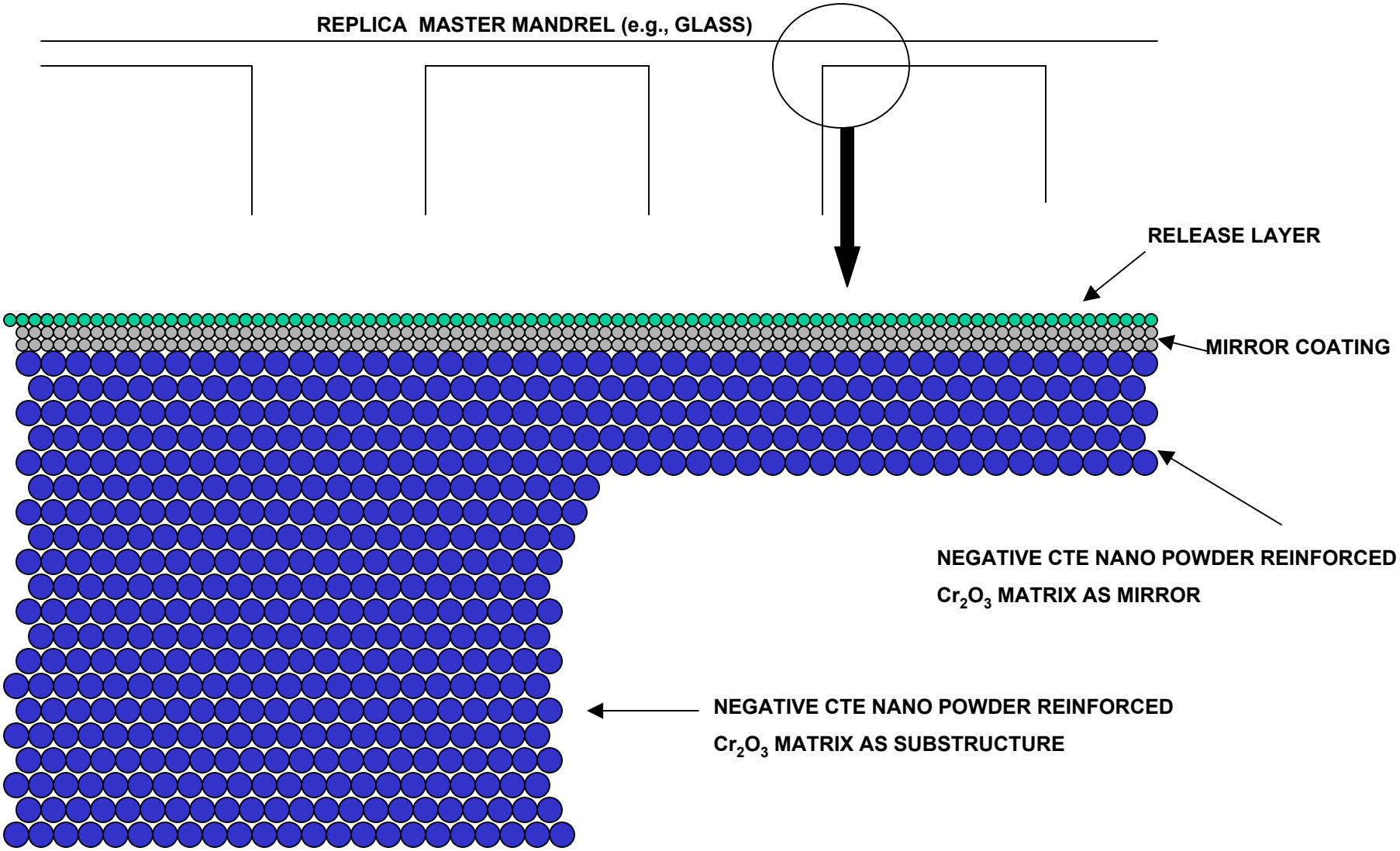
(b)

SEM Photomicrographs of ZrW_2O_8 Powder (UES)
(a) After Dehydration, and (b) After Calcination

Geopolymerization



Schematic Drawing of - CTE Nano-Powder Reinforced CDD Processed Uni-Body Composite Mirror Assembly Concept



Chemically Driven Densification (CDD) process

Reaction:

1) $CrO_{3(s)} \rightarrow 0.5\ Cr_2O_{3(s)} + 0.75\ O_2$ @ ~650°C in air

CrO_3: m.p. = 197°C; decomposition T. = 250°C

2) Cr-bearing gas (e.g., $CrO_{3(g)}$)➔Condensation & Nucleation ($Cr_2O_{3(s)}$) ➔Densification

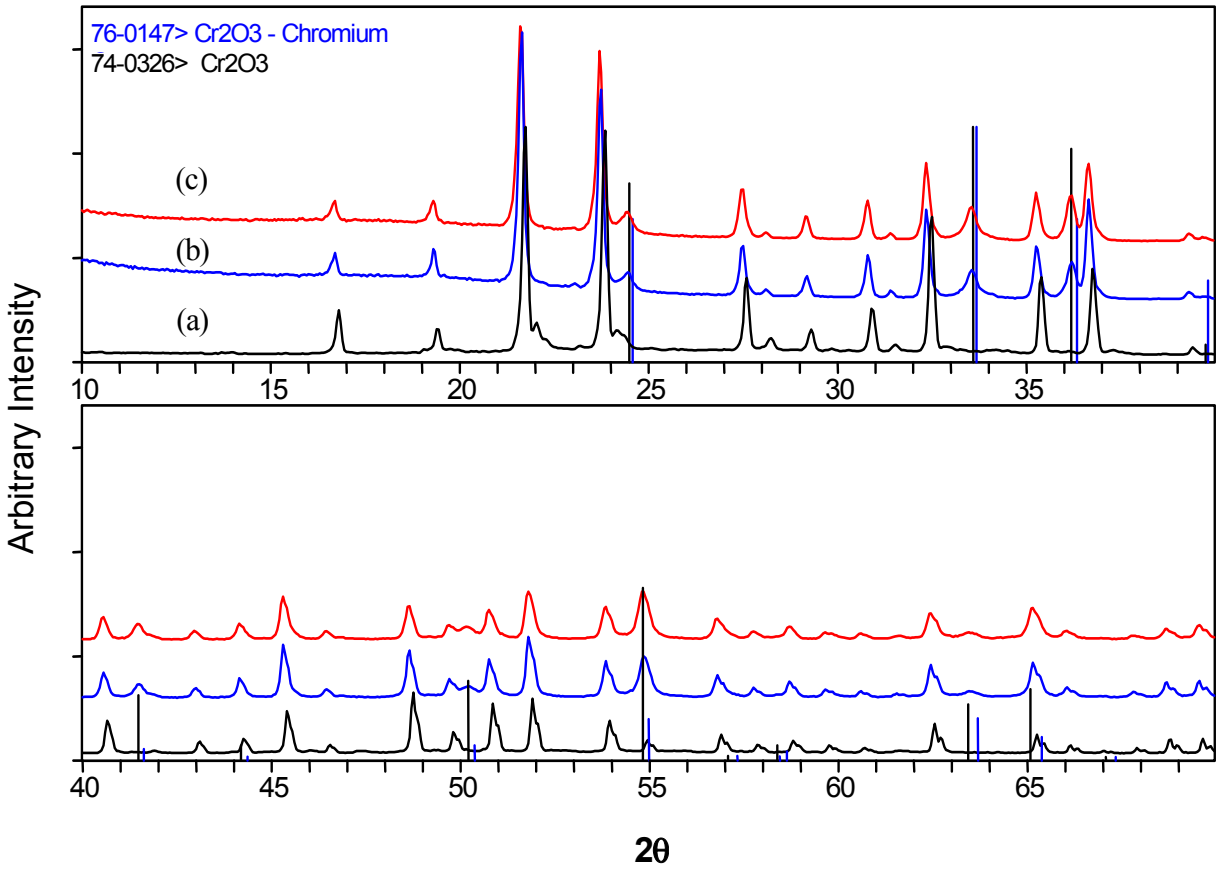
Examples/Experiences:

Densification of Porous Alumina matrix in CMC

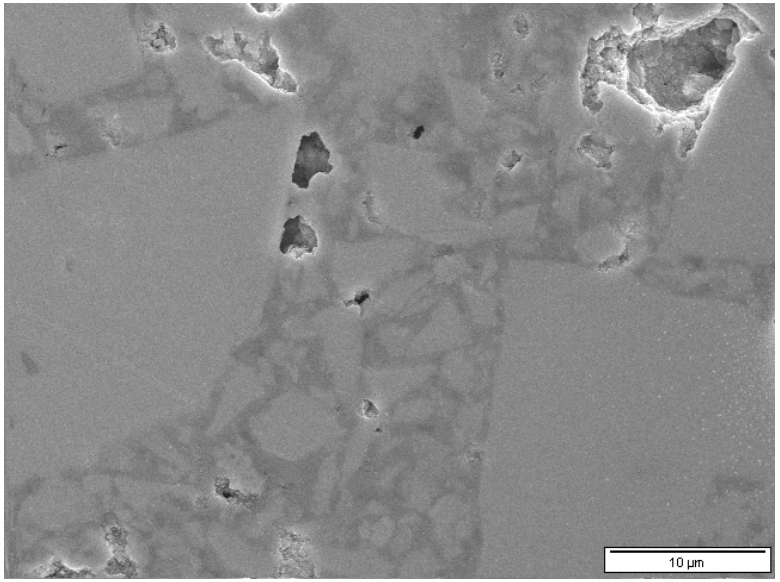
Current Process:

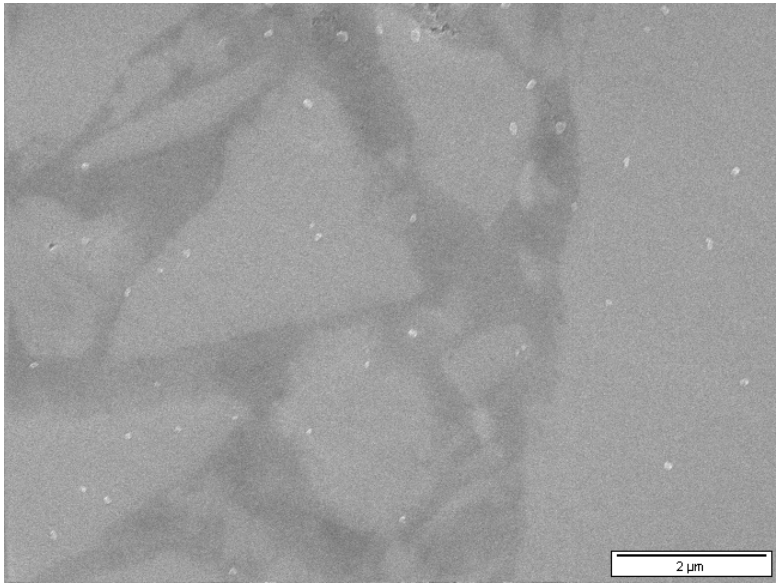
Multiple-Infiltration and Pyrolysis of CrO_3/H_2O Solution into Commercial (Wah Chang) Negative CTE Powder (ZrW_2O_8) Preform

Future Work: Use ZrW_2O_8 Nano-Powder (UES)



Powder diffraction patterns of (a) ZrW_2O_8, (b) ZrW_2O_8-Cr_2O_3 (3 cycles), and (c) ZrW_2O_8-Cr_2O_3 (5 cycles)





SEM Photomicrographs of ZrW_2O_8 –Cr_2O_3 Composite showing insufficient densification due to the presence of large ZrW_2O_8 particles (Wah Chang).

High Magnification shows full densification near fine ZrW_2O_8 particles.

Average grain size of CDD processed Cr_2O_3 matrix is about 25 nm.

(Grey phase = ZrW_2O_8 , Dark phase = Cr_2O_3)

SUMMARY

* Preliminary Experimental Work on All the Key Processing Issues were Successfully Explored:
  - Nano-Laminate Deposition
  - Release Layer Deposition
  - Negative CTE Nano-Powder Synthesis
  - Suitable Geopolymer Synthesis
  - CDD processing with Negative CTE powder

* Base on the Preliminary Work, the Proposed Concepts are Appeared to be Viable

FUTURE WORK

* Nano-Laminate Deposition Process Optimization
* Best Release Layer Selection and Experimentation
* Negative CTE Nano-Powder Production in Large Quantity
* Bond Strength Measurement between SiC and SiC using Negative Nano Negative CTE powder Reinforced Geopolymer
* CDD Processing using Nano-sized Negative CTE Powder Preform and Characterization
* Microstructural Characterization and Physical Property (e.g., CTE) Measurement of Nano-Laminate
* Based on the Optimization Study, Down Select or Modify the Proposed Concept will be Proposed to Study in for Phase II